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(Reprinted from the "Westminster Review," for April 1873.)

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NEARLY all great modern scientific discoveries have been made by teachers of science and others, who spent a large portion of their lives in experimental investigation, searching for new truths, and not by persons who have hit upon them by accident. The greatest discoveries in physics and chemistry in modern times were made chiefly by such men as Newton, Cavendish, Scheele, Priestley, Oersted, Volta, Davy, and Faraday; all great workers in science.

It is by observing matter and its forces under new conditions that many discoveries are made; thus Priestley placed some oxide of mercury in an inverted glass vessel, and heated it by means of a lens and the sun's rays, and discovered Oxygen. Oxygen was nearly discovered by Eck de Sulsbach three hundred years before; he heated six pounds of an amalgam of silver and mercury, and converted the latter metal into a red oxide like cinnabar, and he remarked, "a spirit is united with the metal, and what proves it is this, that this artificial cinnabar submitted to distillation, disengages that spirit." The "spirit" was evidently oxygen.

Some kinds of discoveries are made by observing the phenomena of bodies placed under special conditions by those operations of nature over which we have little or no control. All our knowledge of astronomy, and much of that of geology and physiology, was acquired in this way.

In nearly all modern discoveries of importance, in physics or chemistry, long and difficult investigations had to be made in order to completely establish their truth. When Crookes discovered Thallium, he saw the first sign of its existence as a momentary flash of green light in a spec-

troscope, but he had to expend upon the subject several years of most difficult labour, and a considerable sum of money, in order to prove the correctness of his suspicion that he had discovered a new metal.

Discoveries differ from inventions; a scientific discovery is a newly found truth in science, which in the great majority of cases is not in the form of a saleable commodity, but may be used for the purposes of ordinary scientific instruction. An invention is usually a combination and application to some useful or desired purpose of scientific truths which have been previously discovered.

Immediately a discovery is made it becomes published and incorporated in all the ordinary text-books of science; and in this way such books have become filled with valuable knowledge acquired by researches in past times, and this accumulated learning is ready for dissemination by teachers of science, and for inventors to apply to useful purposes. All this knowledge (which is of enormous value, and has cost a vast amount of intellect and labour) has been given freely to the nation without money and without price.

The most abstract and apparently trivial experiments in original research have in some cases led to inventions and results of national importance. The contractions of a frog's leg in the experiments of Galvani, and the movements of a magnetic needle in those of Oersted, have already led to the expenditure of many millions of pounds in laying telegraph wires over many parts of the earth, and to an immense extension of international intercourse. But the original experiment of Oersted was not discovered without labour; it was only arrived at after many years of research.

The discovery in olden times of the attractive properties of a fragment of iron-ore, was the basis of the invention of the mariner's-compass, which greatly improved navigation, and led to nearly all the chief maritime discoveries which have since been made. It enabled sailing vessels to venture freely out of sight of land, and to traverse the open ocean with even greater safety than to sail near the shore. By its means Columbus crossed the Atlantic Ocean and discovered America. By its means also, Vasco de Gama sailed round the Cape of Good Hope and discovered a new route to India; and in the year 1500, another Portuguese Captain, Cabral, was driven across the Atlantic, discovered Brazil, and was enabled by the aid of the magnet, to send back a ship to Lisbon with news of the discovery. By its assistance also, Magellan discovered Patagonia and the South Pacific Ocean; and by the completion of that voyage the earth was first circumnavigated and proved to be a globe. With the aid of the same means, others discovered Australia and New Zealand, and ultimately completed the maritime geography of the whole world. By the same means, at the present time, every mariner directs with certainty the course of his ship, and innumerable cargoes of enormous aggregate value, are safely conveyed to all parts of the globe.

The geographical discoveries of the Portuguese, made by means of the magnet, produced great national results; they profoundly changed the balance of power and wealth amongst the European nations, by changing

the direction of navigation and of the great streams of commerce between Europe and the East. They gave a mortal blow to Italy and the cities of the Mediterranean, by transferring Eastern commerce to Spain and Portugal; and Egypt ceased to be the greatest route of commerce from Europe to India.

The discovery of the properties of a mixture of nitre, sulphur, and charcoal, which occurred at about the same time as the invention of the mariner's-compass, led to the use of gunpowder, which changed the whole method of warfare, and made mere animal strength a less advantage in fighting.

Never were nations so rapidly enriched as those of Spain and Portugal by means of the magnet and gunpowder. Spain brought home immense quantities of gold and silver from Mexico; Portugal imported diamonds from Brazil, and riches of all kinds from India and the East.

Scientific discovery has in all ages been a most powerful agent of civilization and human progress. The discovery of the black liquid which a solution of nut-galls produces when mixed with green-vitriol, led to the invention of writing-ink; and a knowledge of the properties of ink and paper prepared the way for the invention of printing, by means of which learning has been spread all over the earth.

The apparently insignificant property possessed by amber, of attracting feathers immediately after it has been rubbed, was known twenty-four hundred years ago, and led in modern times to the discovery of electricity. In still later times, Dr. Franklin, by means of a kite, charged a bottle with lightning, examined it, and proved lightning and electricity to be identical. This knowledge, joined to the further discovery, that electricity would pass freely through metals, led to the invention of the lightning conductor, by means of which all our great buildings, ships, lighthouses, arsenals, and powder magazines are effectually protected from lightning.

"Coming events cast their shadows before:" the discovery of the instant transmission of electricity along wires foreshadowed the invention of the electric telegraph. About the year 1815, Oersted, a Danish philosopher, after fifteen years of study and experiment, to ascertain the relation of electricity to magnetism, discovered that if a freely suspended magnetic needle was supported parallel to a wire, and an electric current then passed through the wire, the needle moved and placed itself at right-angles to the current. This discovery, coupled with the previous one of the electric conductivity of metals, formed the indispensable foundation of all our present electric telegraphs.

Original research is more productive of new industries and inventions than any other kind of labour. The researches of Volta, Faraday, and many other investigators, have led to the process of electro-plating, the use of electric lights for light-houses, and the great system of telegraphs. Those of Davy, Wedgwood, and others, respecting the action of light upon salts of silver, have led to the modern processes of photography, which are now in use almost everywhere. The discovery of zinc by

Paracelsus, has been followed by the use of that metal in galvanic batteries, and the great use of "galvanized" iron for telegraph wires, for roofing, and many other purposes. The discovery of nickel by Cronstedt has led to the great modern use of German-silver in the construction of electro-plated and other articles. The discovery of chlorine by Scheele formed the basis of nearly all our our modern processes of bleaching cotton and other fabrics. The discovery of gun-cotton and nitro-glycerine has led to the use of those substances in blasting rocks and in warfare. The discovery of oxygen by Priestley, has enabled us to understand and improve in a great number of ways, the numerous manufacturing, agricultural, and other processes in which that substance operates. The discoveries of gutta-percha and India-rubber were the origin of the great use of those substances in telegraph cables, and in a multitude of useful articles. The discovery of chloroform and anæsthetics, has led to their use for the purpose of alleviating human suffering. The discovery of phosphorus led to the erection of the large manufactories of that substance and of lucifer-matches, and to the use of those matches all over the earth. The discovery by Sir Isaac Newton of the decomposition of light by means of a prism, has led in recent times to the invention of the spectroscope; to the use of that instrument in the Bessemer-steel process; to the discovery of four new metals, thallium, rubidium, cæsium, and indium, and to the most wonderful discovery of the composition of the sun and distant heavenly bodies.

Even the invention of the steam-engine was partly a consequence of previous researches of scientific men. Watt himself stated in his pamphlet entitled "A Plain Story," that he could not have perfected his engine, had not Dr. Black and others previously discovered what amount of heat was rendered latent by the conversion of water into steam. Had not the steam-engine been developed, it is clear that railways, steam-ships, and all the numerous uses to which that noble instrument is now applied, would have been comparatively unknown. The discoveries of nitric-acid, hydrocloric acid, oil of vitriol, and washing-soda, by the alchemists and early chemists in their researches, led to the erection of the numerous great manufactories of those substances which now exist in England and in other civilized countries. There is probably not an art, process, or manufacture, which is not largely due to scientific discovery, and if we trace them back to their source, we nearly always find them originate in scientific research.

Discovery is usually the basis of invention; a man cannot generally invent an improvement unless he possesses scientific knowledge, and for that knowledge he must in nearly all cases resort to a scientific book or teacher. Nearly all the pure scientific knowledge contained in books was obtained by original research, and the great bulk of valuable patented inventions was made with the aid of that information. The discovery of a single substance, such as oil of vitriol, or washing-soda, has led to the formation of many valuable inventions, patented or otherwise, and to the establishment of more than one hundred manufactories.

Judging by means of the experience already acquired, we cannot reasonably expect that discoveries fraught with such momentous consequences as those of magnetism, or of galvanism and electro-magnetism, will be made very often. The progress of scientific discovery is gradual; we have at present but glimpses of the new world of truth which is being revealed to us by means of research; we are only at the very commencement of a knowledge of the inherent properties of matter and its forces, and consequently the methods we employ to utilize them are extremely imperfect. Discoveries probably remain to be made which will enable us to convert the various forces into each other without division or loss; at present we can scarcely do so in any instance. By the steam-engine, that marvellous result of modern intellect, we only obtain available for our uses about one-eighth of the mechanical power producible by coal. Matter has a general property of subdividing forces; if we put one force into a substance or machine, it produces many effects, not only those we want, but those also we do not want: when we heat a piece of iron, the heat produces a number of changes, mechanical, electric, magnetic, and chemical, and it is by means of what is termed the "internal resistance" of bodies that these effects are produced, and we know but little of that property. The explosive action in a gas-engine produces not only the mechanical force we desire, but also a quantity of heat we do not want, and at a cost of a portion of the gas. In a similar manner, in the steam-engine much of the heat of the coal is converted into forces which are lost; a large amount of it is uselessly expended in warming the machine itself and the surrounding atmosphere; much also is lost by friction. Discoveries probably also remain to be made which will enable us to completely utilize solar heat and tidal energy. The total amount of solar heat which falls upon this earth in twenty-four hours, would, if converted into mechanical power, be equal to that of an immense number of horses; the average of that which falls annually upon a square foot of terrestrial surface would lift fifty-two tons weight one mile high. The total mechanical value of the tidal energy of all the water on this globe is also an amazing amount.

That "knowledge is power" is an old maxim, but that *new knowledge is new power* is a new maxim which scientific discovery has impressed upon us. By means of discoveries we have acquired new powers; by those of Electricity we have acquired the power of conversing with each other at unlimited distances, and by means of those in Optics we are enabled to analyze the composition, and perceive some of the physical changes of the most distant heavenly bodies.

Experience in science has shown that it is by means of inventions based upon *new* discoveries that the greatest utilities are obtained, rather than by the exercise of invention upon knowledge acquired long ago. The knowledge obtained by research in ancient times has been largely exhausted for the purposes of invention by modern inventors, and what we very greatly require now is *new* knowledge. Experience in science also leads us to believe that the extent of possible discovery is as bound-

less as Nature, and that an immense amount of new knowledge may yet be discovered. Every discoverer of repute could supply a copious list of investigations yet to be made.

A very great amount of the wealth of this nation has been obtained by the application of scientific knowledge to the substances and forces by which we are surrounded. Who can estimate the money-value of the application of such knowledge to coal, by enabling it to produce mechanical power in the steam-engine and gas-engine; to evolve light by means of coal-gas; to yield the beautiful aniline dyes; and to be used as a source of ammonia?

Nearly every manufacturer in this country is deriving from scientific discoveries advantages for which there has been made little or no payment to the discoverers. The makers of coal-tar-dyes and the dyers of wool and silk are using Mitscherlich's discovery of nitro-benzine. Manufacturers of picric acid and "French purple" have enjoyed the fruits of the labours of Dr. Stenhouse. Makers of chlorate of potash are profiting largely by the discoveries of Scheele, Gay-Lussac, and others. The various telegraph companies, copper-smelters, and makers of copper telegraph wire, are using Dr. Matthiessen's discovery of the influence of impurities on the electric conducting power of copper. Phosphorus-makers are reaping the reward of the labours of Gahn and Scheele. The makers of electro-plate and of German-silver are deriving great profits from the labours of Faraday and Gay-Lussac. Makers of Bessemer-steel enjoy advantages derived from the spectrum discoveries of Kirchoff. Iron and copper-smelters, metallurgists, dyers, calico-printers, bleachers, brewers, makers of vinegar, white-lead, red-lead, varnishes, colours, soaps, green-vitriol, phosphorus, oil of vitriol, and many others, are deriving benefit from the discoveries of Priestley and Scheele. Physicians also are receiving the reward of the labours of Soubeiran, Liebig, and Dumas, in the discovery of chloroform; of the researches of Fourcroy, Vanquelin, Pelletier, and others, in the discovery of quinine; and of many other chemists, in the discovery of numerous remedial substances.

The great pecuniary benefits arising from the applications of science are generally reaped in the first instance by the great manufacturers, agriculturists, merchants, and capitalists. Countless fortunes have been made by means of processes and manufactures based upon scientic discovery. The pecuniary profits of the great manufacturers of cotton, copper, iron, pottery, beer, sugar, glass, spirits, vinegar, gutta-percha, india-rubber, gun-cotton, the various metals, machinery, electro-plate, washing soda, German-silver, brass, phosphorus, manures, the common acids, the various chemicals, and a multitude of other substances and articles, have been extremely great. The pecuniary advantages of the use of the electric telegraph and railways to merchants;—the gains of capitalists by money invested in railways, telegraphs, steam-ships, gas-works, iron shipbuilding, engineering, and other great applications of science, have been enormous. The money expended upon the construction of railways alone in this country has already amounted to more than

five hundred and fifty millions of pounds, and the total receipts upon British railways has reached forty-three millions per annum.

In a general way, the greatest pecuniary benefits arising from science, sooner or later go to enrich the possessors of land. The demand created for coal, iron, lime, building-stone, and all the metals, by the industrial applications of science, has greatly increased the value of land under which those substances lie. The value of cultivated land has been everywhere increased by the discoveries of agricultural chemistry. Land has also been required for railways in nearly all parts of the kingdom, and has thereby been considerably raised in value. Discoveries produce inventions, inventions give rise to processes and manufactures, the employment of workmen and others, and the erection of workshops and dwellings, and these have rapidly increased the value of building ground. In Lancashire the value of such ground has been greatly increased by the invention of the steam-engine, the discovery of chlorine, and their application to the cotton manufacture. In all the great manufacturing districts, and in all the chief centres of industry, a similar result has occurred. Wherever a railway has been constructed in Great Britain, the value of land has increased in consequence of the increased facilities of communication. All these great additions to the value of land are largely due to the unpaid labours of scientific discoverers, and it may be said that this nation has largely gained its wealth, and is still living in a great degree on the products of those labours. Those great additions to the value of land are also permanent, are continually increasing, and are largely independent of any exertion on the part of the owners.

There is not a man in this kingdom who has not derived some advantage, in one way or another, from scientific research. The advantages of gas light, rapid postal service and transmission of goods, railway travelling, cotton apparel, photography, cheap pottery, improved medicine and surgery, Australian preserved meats, &c., &c., have been reaped more or less by everyone, even the very paupers. Science has also, by developing new processes, given employment to whole armies of workmen in numerous arts, manufactures, and occupations. About a quarter of a million persons are employed on the railways alone in Great Britain, besides those who were engaged in their construction; and in the postal-department alone of the telegraph service of this country more than fifteen thousand operatives are employed. Chemical works also find employment for twenty-six thousand, and gas-works for ten thousand workpeople.

It would be altogether a false argument to say that the practical benefits derived from the labours of discoverers by the different classes of the community are small or imaginary, because the discoveries and the benefits are not immediately connected. We know that the consumers of tea in this country derive benefit from the grower of that herb in China through the hands of a series of intervening agents, as certainly as if they received the tea direct from his hands.

Much of the wealth of this country, resulting from science, has been very easily obtained by its possessors. That acquired by means of our

coal has especially been obtained without commensurate effort. To draw upon a mine of coal is much like drawing upon a bank of money, because coal is a great store of power; it differs from nearly all other abundant substances by containing an immense amount of latent chemical energy, which may at any moment, and with scarcely any expenditure of labour on our part, be converted into heat and mechanical power in the steam-engine. Every piece of coal contains sufficient latent power to lift itself a height of more than two thousand miles, but it costs only a small proportion of that power to extract and raise it from the mine. We do not mean by these remarks to imply that the wealth accruing from this great store of power in coal, is derived chiefly by the owners of coal mines.

An excess of money or power, obtained without commensurate effort, fails to properly develop the intelligence of its possessor, and nations have been hastened to ruin in this way. The wealth of the upper classes of this nation has, by decoying from study undisciplined young men at our old Universities, kept down the general standard of scientific instruction throughout the country, and by leading to neglect of scientific research, is now retarding our progress in arts, manufactures, commerce, and civilization. The great poverty of the working classes is also producing similar effects by retarding education, and increasing the great want of skilled labour of which our inventors, manufacturers and others, so strongly complain in the working of their scientific processes. Had a just share of the great amount of money gained by the applications of science to useful purposes, been applied to the payment and maintenance of scientific discoverers, as it should have been, the wealthy would have been more intelligent, the poor would have had more employment and money, and the happiness and civilization of all would have been greater.

Of the great multitude of rich manufacturers, merchants, capitalists, and landowners in this country, who have derived such great pecuniary benefits from original scientific research, we believe there is scarcely a man existing who has ever given to a scientific society, institution or investigator, a single thousand pounds for the aid of pure research in experimental physics or chemistry; the nearest approach to exceptions are a very few wealthy persons who have devoted themselves personally to scientific discovery. Many of those manufacturers and others would however willingly give money towards such an object, if they understood the value and necessity of scientific research.

Whilst many millions of pounds are annually expended in this country upon religious, philanthropic, and other good objects, there is scarcely a scientific society or institution (with the exception of the British Association), which expends even the small sum of five hundred pounds a year on pure experimental research in physics or chemistry. In the Royal Institution of Great Britain, the average annual expenses relating to experimental research, including salaries to assistants in the laboratory, from the year 1867 to 1871, did not amount to two hundred and fifty pounds.

Considering the multiplicity and variety of philanthropic institutions

and bequests in this country, and the great effect original scientific research has in ameliorating the condition of mankind, and reducing the amount of human misery, it is surprising that no wealthy philanthropic individual has bequeathed funds for the endowment of an institution for pure research in physics or chemistry. In America, the "Smithsonian Institution" was founded at Washington by a benevolent and patriotic person "for the increase and diffusion of knowledge among men," and one of the objects of that institution is "to enlarge the existing stock of knowledge by the addition of new truths;" and a portion of its plan is "to stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths," and "to appropriate annually a portion of the income for particular researches."

Many persons in this country look upon scientific research either as a hobby, or as a refined intellectual pursuit, and do not view it as an important or essential element of National greatness and progress. Persons in general in this country also consider such research as unpractical, but this is simply in consequence of their ignorance of the subject; if discoveries were commercial commodities, the practical character of research would then be within their comprehension. Scientific discoverers may be considered the most practical men in existence, because their labours give rise to greater and more numerous practical results than those of any other persons. A man who cultivates plants for the purpose of obtaining the seed, is quite as practical a person as he who converts that seed into vegetables fit for human consumption.

In addition to the great benefits accruing from original research to all classes of society, our Governments have also derived immense advantages from the same source. The revenues have been greatly increased by the universal advantages conferred upon all kinds of industry and commerce by scientific knowledge. The additional taxes upon increased incomes arising from agriculture, arts, manufactures, mines; increased value of land and rents; investments in railway, telegraph, steam-ship, and other companies, have been extremely great. From the sale of Patents alone, a surplus sum of nearly six hundred thousand pounds has already accumulated. Our Governments are also indebted to original research for the use of percussion-powder, gun-cotton, improvements in cannon, projectiles, rifles, armour-plated ships, the ocean telegraph, field telegraph, rapid postal communication, the speedy transport of troops and war material, and a multitude of other advantages. The value of science to Governments in the prevention of war by means of more ready correspondence through telegraphs is incalculable.

As the knowledge resulting from scientific inquiry has been of such immense value to this nation, one would suppose that such inquiry would be greatly encouraged and highly rewarded. The reverse is, however, the case; research in physics and chemistry has for years been declining in this country, chiefly in consequence of the neglect with which it has been treated. Most of our ablest investigators in those subjects have ceased to make researches. Several also, Faraday, Graham, Matthiessen,

and Miller, have died, and others have not arisen to supply their places. Able discoverers are rare, and the loss of even a few such men in a country is a national calamity. At the present time the proportion of such men amongst us wholly engaged in research is less than one in a million of the population.

Whilst the number of original researches in physical and chemical science has been increasing on the Continent, especially in Germany, it has been decreasing in England. The Journal of the Chemical Society, which was formerly filled with original researches made by British chemists, is now almost entirely occupied with the abstracts only of researches made elsewhere, and we are rapidly becoming dependent upon foreign nations for a supply of new scientific knowledge. According to a statement of Dr. E. Frankland, the number of published scientific researches in the year 1866 was in Germany, 777, France 245, and Great Britain 127.

It is more difficult to carry on original research in England now than it was twenty years ago, because scientific employments of a much more lucrative kind have greatly multiplied, and attract men of science from pursuing discovery; the means also for prosecuting research have not increased, whilst the expenses of living have become much greater; nearly all other useful occupations have advanced and left scientific inquiry behind.

Whilst vast sums of money are spent upon the applications of science in military and naval affairs, research itself is neglected: the superstructure is attended to, but the foundations are left to decay. Our Governments have as yet made no payment for the labour of pure research in experimental physics or chemistry; they have given a thousand pounds a year to be distributed by the Royal Society amongst scientific investigators, but a grant from this sum is an unprofitable gift to accept, because it is only sufficient to partly pay expenses out of pocket for chemicals and apparatus, and allows nothing for skill or labour. Investigators frequently, for this reason, do not avail themselves of the fund.

So defective are the arrangements of our Governments with regard to science, that gentlemen comparatively ignorant of it are appointed to decide the various scientific questions of national importance that arise, and to direct scientific men in their own special departments. Quite recently (May 1872), a memorial, signed by the eminent investigator, Sir William Thomson, was sent by the British Association to the Lords of the Treasury, applying for 150*l.* to continue researches on the tides; but notwithstanding that we spend immense sums of money on ships, and a knowledge of the tides is essential to the safety of those costly vessels, the small sum asked for so important a purpose was refused. Not one of the gentlemen appointed to consider this application is known as an authority in scientific research. Another recent instance, that of the First Commissioner of Works, and the eminent botanist, Dr. Hooker, is so well known that we abstain from describing it. The teachers of science also in nearly all our Grammar-schools, are subject to the direction of

unscientific head-masters, who are appointed in accordance with the recommendations of Government Commissioners, with power to choose the scientific books and control the method of teaching science in those schools.

Want of recognition of the value of science has been so general in this country, that it is quite pleasing to quote a somewhat different case from *The Illustrated London News*, January 4, 1873—viz., that of Archibald Smith, LL.D., F.R.S., who recently died. That gentleman was an investigator in pure mathematical science, and devoted the latter part of his life to the application of his mathematics in the computation, reduction, and discussion of the deviation of the mariner's-compass in wooden and iron ships, and made practical deductions therefrom in the construction of those vessels.

He published those practical applications of his scientific knowledge in the form of an Admiralty Manual, which was afterwards republished in various languages. Her Majesty's Government, not along ago, "requested his acceptance of a gift of two thousand pounds, not as a reward, but as a mark of appreciation of the value of his researches, and of the influence they were exercising on the maritime interests of England and of the world at large."

The case of Dr. J. Stenhouse, F.R.S., is one of rather an opposite kind. That gentleman devoted his life throughout to pure investigations in organic chemistry, and published several of his researches in the Philosophical Transactions of the Royal Society. His discoveries are very numerous, and although not much applied to practical uses by himself, the results of his researches on Lichens, and on the yellow gum of Botany Bay, have been applied extensively by others in the manufacture of "French-purple" and picric acid, and will doubtless continue to be applied to valuable uses by other persons. He held the Government appointment of Assayer to the Royal Mint, London, an office for several years unprofitable to him, but of rapidly increasing remunerative value, and which would now have been worth 1200*l.* a year; but after the decease of his colleague Dr. Miller in 1870, that office which was then worth to him about 600*l.* a year, was abolished by the Chancellor of the Exchequer, and he lost the appointment, receiving, however, 500*l.* as compensation. An application was therefore made to the Government, and a partial recompense to him was obtained, by her Majesty granting him one hundred pounds a year "for eminence in chemical attainments, and on account of loss by suppression of office in the Mint."

The only difference in these two instances was, that in the second there was a very much greater amount of pure research and discovery, and a much smaller degree of applied knowledge.*

These instances also illustrate the statement, that however great an amount of valuable knowledge in pure science a man may discover and publish, or however freely he may provide others with the materials of

* See "Royal Society Catalogue of Scientific Papers," vol. v. pp. 717 and 819.

invention and wealth, if he never invents anything, nor applies his knowledge to useful purposes, he is usually less rewarded even than an inventor.

In harmony with these instances, we find that it is not the pure sciences, but the concrete and the applied ones, such as meteorology, geology, natural history, &c., in the Meteorological Department, the Geological Survey, the British and South Kensington Museums, the Geological Museum, &c., which have received the greatest degree of support from our Governments.

It is believed to be a duty of the state to provide and pay for pure scientific research for the following reasons:—because the results of such labour are indispensable to national welfare and progress; because the results are of immense value to the nation, and especially to the Government; because nearly the whole pecuniary benefit of it goes to the nation, and scarcely any to the discoverer; because research cannot be efficiently provided for by means of voluntary effort; and because there appears to be scarcely any other way (except by application of University revenues) in which discoverers can be satisfactorily paid for their labour.

There are also many experiments, investigations, and explorations bearing upon scientific discovery, which neither private individuals, nor even corporate bodies, such as the Royal Society, the British Association, or Geographical Society, can effectually make, and which only a Government can carry out, such as Arctic expeditions, trigonometrical surveys, deep-sea dredging operations, magnetic observations, determinations of longitude, meteorological and astronomical observations, researches on tides, observations of earthquakes, determinations of the height of mountains and of the density of the crust of the earth, experiments on the best form of ships, geographical explorations, and many others.

It is clear from the enormous advantages which this nation has already derived from scientific discovery in physics and chemistry, pursued with only the aid of the very limited means of private persons, that had research in those subjects been sufficiently supported, the manufactures, arts, commerce, wealth, and civilization of this country would have been much greater than they are; emigration also of the industrious classes, pauperism, and crime, would have been much less. The amount of knowledge and riches obtainable by means of research and invention, is practically unlimited, and it is astonishing that this immense source of industry and wealth in a nation should have been so neglected by our Governments, and permitted to decline; but the most probable explanation is, that our rulers have been ignorant of its great value, and of their duty to utilize it. The practical value of new scientific knowledge is infinitely greater than that of our coal supply, because it would not only enable us to obtain from coal several times the amount of available heat and mechanical power we now secure, but also to apply to our wants the numerous other materials composing the crust of this globe and the contents of our oceans; also all terrestial forces, the internal heat, the tidal energy and atmospheric currents. and the immense amount of power this earth is contiuually receiving from the sun.

It is reasonable to suppose that Universities should be fountains of new theoretical scientific knowledge, as well as be the disseminators of it, and that they (especially the old ones with their rich endowments) would be certain to promote scientific research, as being especially a part of their functions; but such is not the case. Our Universities have not established any professorships of original research; they make no payment for such labour, nor reimburse any expenditure incurred in such occupation, and afford but little facility for the prosecution of pure scientific inquiry. Further, they discourage scientific discovery by giving the greatest emoluments, and the highest honours in science they have to bestow, to young men who have never made a single original research, or discovered a new fact in science. The money paid in the form of comparatively sinecure fellowships, or retiring pensions to young men in Oxford alone, "now amounts to about eighty or ninety thousand pounds a-year." It may be objected, that young men are not capable of doing original research, but as they do it in German Universities, they can also do it in England if they are properly disciplined, and are not decoyed from industry by the possession or expectation of wealth. A man who has never made a scientific research is not the most worthy recipient of the highest scientific honour, and in Germany it would not be given to him; he is not properly disciplined in the detection of error or the discernment of truth in matters of science; he is deficient in accuracy of scientific judgment, and in the true spirit of scientific inquiry.

As the subject of this paper is scientific *research*, it is unnecessary to speak of what has been done during the last few years at our old Universities and great public schools, in the erection of laboratories, and in other ways for the promotion of science, as it has been for the purposes of instruction, and not of original research. No amount of ordinary instruction in science will remedy the evils caused by want of original inquiry, because such instruction does not produce new knowledge, but only disseminates that already possessed.

That discoverers are not treated by us as we treat other valuable members of the community is quite clear; either a physician, a judge, divine, lawyer, or railway superintendent of high ability, obtains from one to many thousand pounds a-year, but a discoverer in pure physics or chemistry is, in scarcely any case, paid anything for his labour. The discoverer, Faraday, received for his scientific lectures only 200*l.* a-year and apartments, during many years, and absolutely nothing for his great discoveries; and during the remainder of his life he only received a few hundred pounds per annum, including a pension of 300*l.* a-year from Government. A general of our army receives 2000*l.* and a Field Marshal, 4400*l.* a-year (see "Whitaker's Almanack," 1873, pp. 121 and 138). A head master of either of the great public schools obtains from 3000*l.* a-year upwards. An Archbishop of Canterbury receives 15,000*l.* a-year, besides a great amount of influence and power in the form of patronage to 183 livings, a palatial residence, and a seat in the House of Peers. A Bishop of London has 10,000*l.*, the patronage of 98 livings, a palace, and a seat in the

House of Lords. (See the "Clergy List," also "Whitaker's Almanack," 1873, p. 155, and "Walford's County Families," 1872, pp. 173 and 610.) We leave our readers to judge to what extent these instances illustrate the statement that discoverers are not treated by us as we treat other valuable members of the community.

It is well known that had Faraday chosen, he might certainly have made a large income as a consulting chemist and scientific advocate, but the love of truth for truth's sake alone was strong in him, and he spontaneously abandoned that course in order to pursue the more important national employment of pure research. It was a statement of his, "I cannot afford to become rich." Discoverers are generally poor, because they are not paid for their labour; and a man cannot usually pursue with success pure scientific research and money, because such research occupies a very great amount of time.

It is scarcely credible that in a wealthy and civilized country, whilst the non-productive classes are most properly protected in the enjoyment of titles and material wealth which they have not earned, the greatest scientific discoverers and benefactors of the nation are constrained to live in a state of comparative poverty whilst working for the pecuniary and other advantages of those classes, and of manufacturers, capitalists, landowners, and the nation in general. By these remarks it is not intended to imply that discoverers are intentionally neglected; but that the circumstances are a disgrace to the nation, and do not reflect any credit upon the governing classes, or especially upon those who reap the greatest advantage.

The men who are rewarded the most highly in this country are not always those who yield the greatest services to the nation, but frequently those who render the most immediate or most apparent benefit; such short-sighted policy as this cannot produce the greatest degree of success. The national services of a great discoverer are immense, and probably not equalled by those of any man. Who can estimate the value of the commercial, social, moral, political, and other great advantages to the world, of the discovery of the principle of electro-magnetism, which enabled the invention of the electric telegraph to be made? The men we pay the highest are not those who discover knowledge, but those who use or apply it; physicians, judges, bishops, lawyers, railway-managers, military and naval officers, and head masters of schools, are all gentlemen who render great services to the nation, by using, diffusing, and applying knowledge already possessed.

Why do scientific investigators in general pursue difficult researches if there is no payment for such labour?—First, from a spirit of inquiry; and second, to obtain high repute in their profession as teachers, &c. No scientific man who entertains a strong sense of the dignity of science, and who in his occupation as a teacher or otherwise, continually perceives the incompleteness of our knowledge of the properties of matter, would willingly spare any amount of labour in order to make that knowledge more complete, especially as he knows that scientific discoveries are of

great value to mankind. If such men had not made discoveries, we should have been without even the conveniences of life, and in a state of comparative barbarism. It need hardly be said that it requires great self-sacrifice on the part of comparatively poor persons, to make difficult, expensive, and often dangerous investigations, without receiving any payment.

It might be supposed that investigators would patent and sell their discoveries; but discoveries in pure science cannot usually be patented or sold, because they have not been converted by invention into commercial commodities. It would also be less to public advantage if investigators were to neglect the more important occupation of discovering new knowledge in order to apply that knowledge to practical uses. It requires a higher quality of mental power to discover new truths, than to utilize them by means of invention; and men who can invent are far more numerous than those who are able to discover. A discoverer creates new knowledge, but an inventor only applies it. Discoveries are also generally much more valuable than inventions, because a single discovery (that of gutta-percha for example), not unfrequently forms the basis of many inventions.

Some persons have suggested that scientific men should keep their discoveries secret, but this would generally be a greater disadvantage to the investigator even than publishing them, and the nation would not then derive the benefit:—discoveries also being often capable of numerous applications, and not being in a saleable shape, cannot usually be monopolized by any one. Discovery is eminently national work, and discoveries are national property. New scientific knowledge is like a powerful light; it cannot be hidden.

Other persons suppose that investigators should be satisfied with the fame of their discoveries, and not require any payment; but this is a most unfair supposition, because no man can live without means, and every useful person deserves to be paid for his labour. Ought the late Duke of Wellington to have been satisfied with the fame alone of his exploits, without being paid any salary? Ought a Bishop to be content with the renown of his eloquence, without receiving any payment for his services? Genius alone is appropriately rewarded by fame, but time, labour and expenditure should be repaid by money.

It has been suggested that an investigator, if he is a man of practical ability, is very often put into an office, the duties of which he can efficiently discharge, and yet have leisure for original research—as in the case of the late Dr. Graham, the eminent Master of the Mint,* our Astronomers Royal, &c.—and thus obtain his reward. But this is a very imperfect plan, because research is very difficult, and to be carried out fully requires the whole of a man's time and attention; the investigator would also be taken from more important work to do that which is of less value to the nation, and which might be performed by a more suitable person; ap-

* The Mastership of the Mint is no longer given to scientific men.

pointments also of the kind referred to are much too few in number. Such a plan as this, of relegating important national work to odd hours spared from official duties, is a makeshift, and quite unworthy of this nation.

Probably the most satisfactory way of rewarding scientific discoverers and serving national interests at the same time, would be to create salaried professorships of original research, and appoint discoverers of repute to fill them.

The great difficulty of determining from what source discoverers should be paid for their labours, arises from the fact that all classes of the community share in the benefit. It is evident they should be paid from a source towards which all classes either directly or indirectly contribute, and therefore from some national fund. The persons who first use new scientific knowledge are the compilers of scientific books, and teachers of science; but these only disseminate the knowledge, and do not derive from it any great pecuniary advantage—they are only the agents for supplying the knowledge to others. The persons who first convert such knowledge into valuable commercial commodities are inventors and manufacturers who have received scientific education or advice; but those who derive the greatest pecuniary benefit from it, and who should therefore either directly or indirectly pay in the largest degree for it, are the great manufacturers, capitalists, and landowners. Whilst the question as to what class of persons shall primarily bear the expense of research is being settled, discoverers themselves are suffering great injustice, research is declining, and our manufactures and commerce are passing into the hands of foreign nations.

What the amount of loss and disadvantage suffered by this nation, through want of encouragement of scientific inquiry is, cannot be estimated, but it is certainly enormous. Had even a very moderate amount of payment been made for such labours, and the expenses out of pocket paid in full, the amount of research performed would have been greatly increased. Under present circumstances, many promising young men, fitted to become good investigators, have been driven out of science altogether. Even amongst our most able discoverers, scarcely one who has not possessed private means has continued research beyond the middle age of life, because such labour enables no provision to be made for old age; and all those who have left have devoted themselves to less important but more lucrative occupations—some to lecturing or teaching, others to compiling scientific books, some to practise as scientific advocates or consulting chemists; some to work out inventions, some to become scientific Commissioners or inspectors of chemical works, others to become manufacturers, patent-agents, managers of works, &c. Most of these gentlemen have been obliged to abandon research at a period of life when their faculties were in the most perfect state for continuing it.

Meanwhile our manufacturers and others in all directions are asking for improvements in their machines and processes; employers of steam-engines want to obtain more power from the coals; makers of washing-

soda wish to recover their lost sulphur; copper-smelters want to utilize the "copper-smoke"; glass makers wish to prevent bad colour in their glass; iron-puddlers want to economize heat; gas companies are desirous of diminishing the leakage of gas; iron-smelters wish to avoid the evil effects of impurities in the iron; manufacturers in general want to utilize their waste products, and prevent their polluting the streams and atmosphere; and so on without end. And inventors are continually trying to supply these demands, by exercising their skill in every possible way, with the aid of the scientific information contained in books; but after putting manufacturers and themselves to great expense, they very frequently fail, not through want of skill, but through want of new knowledge, attainable only by means of pure research. Judging from the vast amount of inventive skill already expended upon the steam-engine, and the small proportion of available mechanical power yet obtained from the coals consumed in it, it is highly probable that a machine for completely converting heat into mechanical force cannot be invented until more scientific knowledge is discovered.

The progress of invention depends upon that of discovery, and these various inventions wanted by manufacturers and others, cannot be perfected until suitable knowledge is found. Every invention has its own appropriate discoveries, by means of which alone can it be perfected; it was not possible to perfect the idea of an electric telegraph before the discoveries of Volta and Oersted were made. An unlimited number of inventions cannot be made by means of a limited amount of scientific knowledge; and our present stock of such information applicable to invention, is very insufficient.

In consequence of this want of new knowledge, manufacturers continue to suffer losses which might be avoided; the high prices of useful articles are maintained; defects in their quality are not improved; preventable accidents continue to happen; the health of workmen continues to suffer; many means of curing diseases remain unknown; medical practice remains full of empiricism, &c., &c. The great sewage question is apparently in this predicament; we are probably trying to solve it without first discovering the requisite knowledge; inventors, engineers, and consulting chemists have racked their brains and have not been able to devise a satisfactory remedy, and the health of the entire population of this country is suffering. If we so neglect the means of ameliorating our condition we deserve to suffer. One would suppose that cholera, contagious diseases, colliery accidents, pollution of air and water, enormous waste of heat from fires, and a multitude of other evils which depend upon physical and chemical conditions, are of but little importance, that we should so neglect one of the most effectual means of preventing them; and it is perfectly clear that by neglecting to aid research, those who gain so much money and advantage from science, are sacrificing national interests (and their own) on an immense scale to personal aggrandizement.

It must not be supposed from these remarks, that discoveries which will enable a man to make any particular invention, can be produced to

order; that is only true to a very limited extent. Men are beggars of nature, and must not expect to be permitted to choose her gifts, or dictate what secrets shall be disclosed. We may however be certain that if we acquire a very much greater supply of new scientific knowledge, we shall then be able to perfect many good inventions, though not exactly of the kind we wish; or in the way we expect. The great sewage question may perhaps be solved in quite an unexpected way, possibly by the discovery of some substance capable of precipitating ammonia and organic matter from their solutions.

What is the reason that scientific research is not encouraged in England? It is chiefly ignorance. There is not a good and important subject, understood by the public, which is not in this country greatly assisted, nor a valuable public servant, whose labours are understood, who does not receive liberal payment and reward; and scientific research and discoverers therefore are neglected, not wilfully, nor because persons are unwilling to encourage good objects, but because scientific discovery and its great value to the nation are so little known. Scarcely a member of our legislature, or of our Universities, is fully acquainted with the national importance of scientific discovery, and it would probably be impossible to find a subject of such great magnitude so little understood. Comparatively few persons have clear ideas of the essential differences between scientific instruction, research, and invention.

Scientific research can only be successfully pursued by employing the highest motive—viz., a love of truth in preference to all things; and this is a condition which very few persons really understand, and a principle which a still smaller number practise. Men in this country are so accustomed to be actuated by the less noble motive of immediate self-interest or of some apparent practical result, that they cannot perceive that in scientific research the most valuable results can only be obtained by employing the highest motive. However necessary and effective the motive of self-interest or of apparent practical result may be in the ordinary affairs of life, it will not enable a man to make many discoveries, because it leads him away from those which are possible, to search for others which may or may not be possible. The beginnings of discoveries are often so very small, that it requires acute senses and observation in order to perceive them; and if the mind is preoccupied with a desire to discover some particular practical object, new phenomena are overlooked. When Faraday discovered magneto-electricity, the first effect he obtained was so very feeble that he could scarcely perceive it. In discovery, man must follow where Nature leads. Some of the greatest practical realities of this age had their origin, not in a search after utilities, but in a search after pure truth, entirely irrespective of any utilities to which it might lead.

Another cause of the want of encouragement of research, is the natural selfishness which exists, though in very different degrees, in all men. Many wealthy persons wish things to remain as they are. Many manufacturers would not aid research unless they could monopolize its

advantages. Students also generally prefer those subjects which are best rewarded, and do not sufficiently consider their intrinsic value. The love of truth for truth's sake alone is very weak in most men, and but few men make the greatest public good their chief object of life. Englishmen in general care less for new scientific knowledge than for the new inventions which result from it.

The extreme ignorance in this country of the value of scientific research, is largely due to the narrowness of the "practical" character of the English mind; men cannot perceive the deep-seated and universal sources of their wealth, and they prefer those occupations which yield the most obvious remunerative results. It is also partly due to scientific investigators themselves not having pleaded their own cause; such men have been so absorbed in the more important occupation of discovery, that they have, probably more than any other class of persons, neglected to enforce the just claims of their own subject. It is however chiefly caused by the influence of misapplied wealth, operating through the old Universities and large public schools. The sons of the wealthy are most of them educated at those institutions, and according to evidence supplied by University authorities to Royal Commissioners, many persons send their sons to those places for other purposes than to acquire learning, and allow them too much money. The considerable wealth of these young men supplies them with attractions which decoy them from industrious study, and the wishes of the parents and students have been largely acquiesced in by the tutors and college authorities. At our old Universities also, physical and chemical knowledge is very much less rewarded than some other subjects, though latterly a considerable improvement has been made in this respect, but even now there is not a University in the kingdom in which a knowledge of scientific research is necessary in order to obtain the highest scientific honour. In these various ways physical and chemical science has been kept very low in our chief seats of learning; and scientific research is wholly neglected by the governing authorities.

The Universities practically determine the kind and amount of scientific instruction in the schools generally of this country, because the boys in the schools are prepared for those institutions in the subjects only which the Universities require, and thus the old Universities have largely been the cause of the low standard of scientific knowledge thioughout the country. The members of our Government, also the head masters of nearly all the Grammar schools, and the upper classes generally in this country, having been mostly educated at our great public schools and old Universities, have remained comparatively ignorant of science, and still less acquainted with scientific research.

Unless a powerful remedy is promptly applied, the present decline of research is likely to continue, because the pursuit of it is continually becoming more difficult, and our scientific investigators are becoming more painfully conscious of the injustice of their position. And should research go on decreasing, and that of other nations increase, we shall

probably continue to fall behind foreign countries in improvements in arts, manufactures, commerce, and all the advantages that flow from science.

The industry of the Germans in scientific research is quite remarkable, as may easily be seen by an inspection of a recent volume of the Journal of the Chemical Society, or of the *Chemical News;* they are availing themselves of the great fountain of knowledge to a much greater extent than ourselves, and are already beginning to reap the reward. Within the last three or four years they have succeeded, by means of researches, in making alizarine, the colouring principle of madder. "England produces immense quantities of benzene, the greatest part of which goes to Germany, there to be converted into aniline dyes, a considerable quantity of which goes back to England. No other country is so far advanced in the manufacture of the coal-tar colours as Germany. The quantity of alizarine manufactured by the German makers far surpasses the English production." (See "Alizarine, Natural and Artificial," by F. Versmann, New York, 1873.) Statements of this kind are frequently published, and made by our manufacturers and others, of the departure of branch after branch of our manufactures to Germany, and of the continually increasing importation of German-made articles.

To remedy this state of things we require a general encouragement of pure scientific inquiry by the State and the Universities. It is thought by some persons who have given special attention to the subject that the State ought to encourage such research and science in general, by appointing a Minister of Science possessing scientific knowledge and good administrative ability; a Scientific Council to advise our Governments in all important matters relating to science; and by establishing State laboratories for pure scientific inquiry, with discoverers of repute in them wholly engaged in research in their respective subjects. It may be difficult to determine the expediency of giving effect to this proposal, but we do not hesitate to urge that some of the funds of each of our Universities should be applied to pure scientific discovery, by the foundation of professorships of original research, and that the highest honours in science should only be given to students who have made a good original research in pure science. The Royal Commission for the Advancement of Science is, however, collecting evidence on the subject from all the leading scientific investigators in the kingdom, and will soon issue a Report containing their recommendations.

In addition to these means, local efforts might be made to encourage research in each great centre of industry; those efforts being excited by issuing a prospectus of the following kind:—

Proposal to Found a Laboratory of pure Scientific Research in ——

As the manufacturers, merchants, capitalists, land-owners, and the public generally, of this town and district have derived, and are still

deriving, great pecuniary and other benefits from the discovery of new knowledge by means of pure research in the sciences of Physics and Chemistry; and as in consequence of the great neglect of such research in this country, and the increased cultivation of it in other lands, especially in Germany, our commerce is suffering, and a great many evils in manufacturing and other operations, in sanitary and many other matters dependent upon physical and chemical conditions, remain unremedied; it is proposed to found a Local Laboratory of original research in those sciences, with every suitable appliance in it; and to employ one or more discoverers of repute, with assistants who shall be wholly engaged in such labour in their respective sciences.

It may be objected that no corporate body can enter into the question of the relative merits of different discoverers proposed to be appointed as professors of original research in such laboratories, but this question is largely decided by the public opinion of scientific men. Any man who had published many original papers in the first-class scientific periodicals or journals of scientific societies, would of course be a discoverer of repute; and any investigator who had published a number of papers in the Philosophical Transactions of the Royal Society might be considered one of the highest ability.

The great difficulty to be surmounted in carrying out any of these schemes, is the very general ignorance in this country of the value and necessity of research, and this can only be overcome by scientific men themselves performing their duty of enlightening the public on the subject. On the other hand, it must not be forgotten that whilst scientific discoverers are waiting for justice, they hold to a great extent the key of the future prosperity of this nation in their hands.

Watson and Ball, Printers, Castle Street, Birmingham.